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Transplanting of Seagrasses with Emphasis on the Importance of Substrate.

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Florida Department of Natural Resources
Marine Research Laboratory

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ABSTRACT

van Breedveld, J. F. 1975. Transplanting of Seagrasses with Emphasis on the Importance of Substrate. Fla. Mar. Res. Publ. No. 17. 26 p. Past seagrass transplant experiments emphasized the use of anchoring devices rather than the suitability of substrate. *Thalassia* needs a reduced (anaerobic) environment, whereas *Halodule* requires an oxidized (aerobic) substrate. *Syringodium* can thrive in either a reduced or oxidized sediment. Transplanting should be done in a clump of 4 to 7 shoots with a few intact rhizome apices; the original substrate is transferred with the plants. Plantings should be done close together thus offering the roots and rhizomes a favorable environment from the beginning and allowing them gradually to stabilize the surrounding area. Additionally, at least three rows should be planted in plot formation for increased protection and transplant success.

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CONTENTS

INTRODUCTION

Seagrass beds form extensive animal spawning grounds and habitats; additionally, grass blades can be lucrative substrates for plant and animal epiphytes as well as being a direct food source for grazing animals such as sea urchins, manatees, turtles, and some fishes (Odum, 1974). Their elaborate rhizome and root systems trap and stabilize the sediments. Thus, seagrass beds are an important part of neritic and estuarine systems (Wood et al., 1969). The three most common seagrasses found in Tampa Bay and Boca Ciega Bay are turtle grass *Thalassia testudinum* Konig, manatee grass *Syringodium filiforme* Kutzing in Hohenacker and shoal grass *Halodule (=Diplanthera) wrightii* Ascherson. They are classified under the Monocotyledonae. Classification to Order and Family still causes differences of opinion among taxonomic experts in this field (Humm, 1973) and shall not be opinioned in this paper. *Ruppia maritima* Linnaeus, a grass-like plant characterized by Phillips (1960), is also found mixed in with the above mentioned seagrasses, most frequently in areas of brackish water (≤25 ‰ salinity). Two other species, *Halophila baillonis* Ascherson ex Dickie in Hooker and *Halophila engelmanii* Ascherson in Neumayer, are less commonly found in Tampa Bay and Boca Ciega Bay.

Although occasional studies of seagrasses have been made since that of Rydberg in 1909, including the worthwhile work of Ostenfeld in 1926, it was not until after the studies of Humm (1956) that more attention was given to morphology, distribution, sedimentation, and ecological value of seagrasses. Many studies have been published since and some are referred to herein.

Humm (1956) described the distribution of seagrasses from the Keys to Mississippi Sound while Phillips (1960) found that local distributions and zonations in Tampa Bay and Boca Ciega Bay were dependent upon the nature of the substrate, salinity, temperature, depth, and turbidity of the water.

Many seagrass beds have been destroyed by man through dredging for buildings, fingerfill canals, and island-hopping for road construction (Figures 1 and 2). Consequently, restoration of these beds would be very beneficial to the reestablishment of the ecosystem. With this in mind, the Florida Department of Natural Resources, Bureau of Marine Science and Technology, initiated a program to determine the feasibility of transplanting seagrasses. If feasible, the contractor, when issued a dredge permit, should be legally bound to restore the dredged area by transplanting.

Attempts by Phillips (1960) to transplant *Thalassia testudinum* were unsuccessful, and those by Kelly et al. (1971) were partly successful. The latter experimented with different anchor devices such as concrete blocks, cans, short pipes, burlap bags, and construction rods. Results indicated that use of construction rods was the best technique tested. In addition, Kelly et al. used hormones and found that 10% NAPH (naphthalene acetic acid) in seawater solution was more effective when applied to rhizomes without apices than with apices. Seemingly, the tender meristematic tissues of the apices could not endure the 10% NAPH solution. These experiments were mostly done with a single shoot or occasionally with two shoots. Little or no sediment was attached to the rhizomes and roots of these single shoot transplants and the root system was immediately dependent upon the new substrate (environment) whether this was suitable or not for the plants. The importance of substrate can be concluded from Patriquin's work (1972), which demonstrated that *Thalassia* is restricted to reduced substrates while *Syringodium* occurs in both oxidized and reduced substrates, and *Halodule* prefers oxidized conditions. The highest mortality (60%) found by Kelly et al. (1971) during the first three months may have been the result of unfavorable substrate in addition to varying effectiveness of an anchoring device. Thorhaug and Stearns (1972) were successful in planting *Thalassia* seeds. Later Thorhaug (1974) successfully planted *Thalassia* seedlings in sediment which had previously supported extensive *Thalassia* beds. These beds had been destroyed by the hot effluent plume of the Turkey Point Power Plant before an adequate cooling system was introduced. The sediment was favorable for the seedlings.

The present study, which started in February 1972, is in effect a continuation of previous studies to establish a reliable method of transplanting seagrasses, especially *Thalassia*.

METHODS AND MATERIALS

EQUIPMENT AND TECHNIQUES

A posthole digger was used to remove seagrasses. Blades of the posthole digger were opened and completely inserted (about 30 cm) into the substrate of a grass bed. By closing the blades, lowering the posthole digger handles to a 30 degree angle and then pulling up the substrate with the seagrasses between the blades, a whole clump approximately

Figure 1. Boca Ciega Bay before dredging of Bayway and Point Brittany.

Figure 2. Boca Ciega Bay after dredging.

12 to 15 cm in diameter was obtained (Figures 3 and 4). These clumps had 4 to 7 short shoots each.

Figure 3. Use of posthole digger to obtain clumps.

Figure 4. *Thalassia* clump in posthole digger.

The longer digger blades cut the rhizomes up to a depth of approximately 30 cm, and only those rhizomes which were below or between the blades were not cut and had apices. For transplanting single plants, a shoot or whole clump was then planted in a hole dug in advance with the posthole digger and the substrate filled in firmly around the plant. When a whole clump was transplanted, it was kept between the blades of the posthole digger and released into the hole (Figure 4). When plants were obtained some distance from the transplant site, individual clumps were released into polyethylene bags and placed in buckets on a floating work table. This table was an epoxyed, 1.2 m x 0.61 m wooden frame with crossbars and a 9 cm thick styrofoam sheet fitted into the frame (Figure 5). When the table was filled to capacity, it was floated to shore or to a boat, and the buckets with transplants were loaded into a car or boat for transportation to the transplant site where the floating work table was again used for holding the clumps.

Various materials were used as growth promoters and anchoring devices. Polyethylene bags were used for single shoots at Plot I-1, rows b, d, and f and for clumps at II-1 by cutting off the top of the bag at the substrate level and cutting holes on the sides and bottom of the bag. In Plot I-1, rows a, c and e, a 19 cm diameter construction rod 10 cm long was used as an anchoring device by attaching it, using wire twisters, in a horizontal position to the

Figure 5. Floating work table.

rhizome of the single shoot. In Plot II-2, one clump was anchored with a construction rod by sticking the rod vertically through the substrate of the clump. In addition, 5% NAPH/seawater and 5%

Root-Dip/seawater solutions (Table 1) were tested as growth promoters both in the field and in the laboratory.

Laboratory experiments were started on January 17, 1972, in two 10-gallon aquaria with seawater of 26.02 ‰ salinity. *Thalassia* clumps and single shoots with rhizomes and apices were dipped for one hour in a 10% NAPH/seawater solution before planting. Controls without soaking were planted in the same aquaria. Each aquarium was aerated with one airstone and lighted with a 40-watt, cool white fluorescent blub from 8 AM to 5 PM. In addition, core samples of sediments to a depth of 7.5 cm and from 7.5 cm to 15 cm were taken from a Cockroach Bay site and at Big Bend site, both in Tampa Bay, and given to Mrs. S. R. Wicks (McKendree College, Lebanon, Ill.) together with *Thalassia* plants from the Cockroach Bay site for chemical and bacterial analyses.

TABLE 1. ROOT-DIP FORMULA

Active ingredients	
Indole 3, Butyric acid	.07%
a-naphtaline Acetimide	.05%
a-naphtaline Acetic acid	.05%
Captan, N-Trichloromethylmercapto-4-cyclohexene-1, 2-dicarboximide	2.00%
Thiram, Tetra Methyl Thiuram Disulfide	2.00%
Inert ingredients	95.83%
Total	100.00%

Thalassia plants for Plots I, III, VIII, IX and X, *Thalassia* and *Syringodium* plants for Plot XII, and *Syringodium* plants for Plot XI were obtained from adjacent beds. Plants for plots II-1 and 2 were obtained from Maximo Point, approximately 2 km drive from the transplant site and for Plots II-3, IV, V, VI, and VII from an area southwest of the second toll of the Bayway/Fort De Soto road, also approximately a 2 km drive. Transplants were taken at least 91 cm from each other, thereby preventing the denuding of a large area in the natural beds.

LOCATIONS OF PLOTS AND PLANTING SYSTEMS

Transplant sites (plots) were located in two general areas:

1) Lassing Park at 19th Avenue and S.E. Beach Drive in St. Petersburg, Florida (Figure 6).
2) Cats Point in Boca Ciega Bay on the N.E. side of the Bayway from St. Petersburg to St. Petersburg Beach, Florida (Figure 7).

Plot I-1 (Figures 6, 8, and 9) was located 185 m east from 1923 S.E. Beach Drive's shoreline in a bare area of 30 by 9 m surrounded by grass beds. The substrate was a soft, dark mud more than 30 cm deep, and the water level was approximately 61 cm at mean low tide. Wave action was minimized by the surrounding grass beds and only very heavy northeast winds could have some effect.

On February 29, 1972, 60 single shoots of *Thalassia* were transplanted in six rows of ten shoots each in a north to south direction, with 46 cm between rows and 30 cm between shoots. One third of the shoots (20) were dipped for one hour in 5% NAPH/seawater, half of which were anchored with 10 cm long construction rods and half with polyethylene bags (rows a and b). One third (20) were dipped for one hour in 5% Root-Dip/seawater, half of which were anchored with construction rods and the other half with polyethylene bags (rows c and d). Of the remaining 20 untreated shoots, ten were anchored with construction rods and ten with polyethylene bags (rows e and f) (Figure 8).

Plot I-2 (Figure 9) was located 30 cm west of Plot I-1. On March 2, 1972, ten clumps of *Thalassia* were transplanted in one row in a north to south direction with clumps 30 cm apart (Figure 8).

Plots II-1, II-2 and II-3 (Figures 7 and 8) were located at Cats Point 252 m along the shoreline from the east side of the first bridge of the Bayway. The three plots were approximately 21 m west from the mean high water line with a depth of approximately 0.9 m at mean low tide. Substrate to a depth of 18 cm was hard, whitish sand and shell, below which it darkened. Wave action was heavy due to boat traffic and lack of protection from winds out of a quadrant from the southwest to north.

On March 21, 1972, ten *Thalassia* clumps were transplanted in Plot II-1 in one row in a south to north direction. Each of the first five clumps were anchored with a polyethylene bag, the ninth with a construction rod and the remaining four were unanchored (Figures 7 and 8). On April 25, 1972, ten *Thalassia* clumps were transplanted in Plot II-2 in one row in continuation of the row in Plot II-1. All the clumps in Plot II-1 and II-2 were 30 cm apart. On May 25 and 26, 1972, 20 *Thalassia* clumps were transplanted in Plot II-3 in four rows, 46 cm apart, of five plants each, 30 cm apart and 30 cm south of Plot II-1 (Figures 7 and 8).

Plots III-1 and III-2 were located at Lassing Park (Figures 6 and 9), 85 m east of Plot I-1. These plots started on the south side of a *Thalassia* bed and stretched out over a bare sand strip for 16 m, ¾

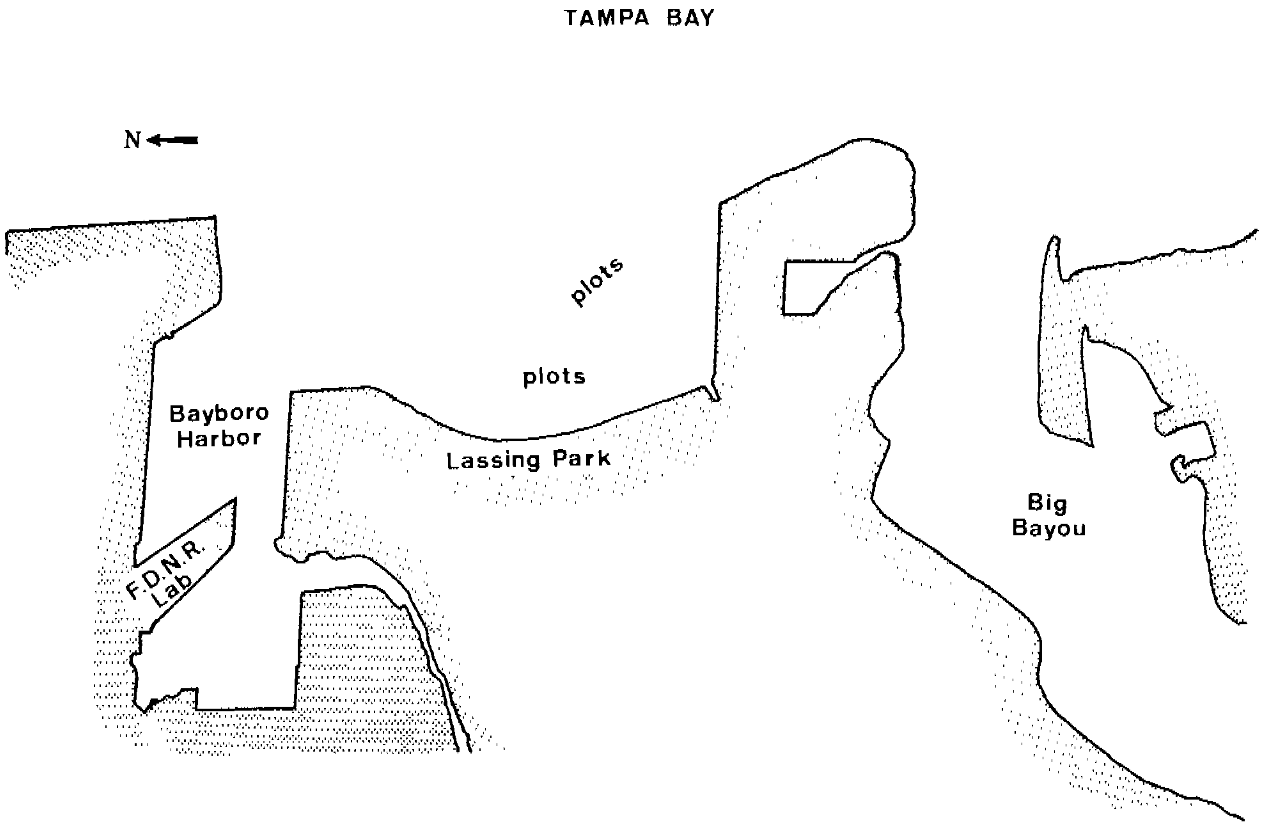

Figure 6. Lassing Park, St. Petersburg, Florida.

of which became dry at spring low tide with less than 30 cm water depth at mean low tide. It was unprotected and subject to wave action. Substrate was hard, whitish sand to a depth of 18 cm, with coloring of sulphur bacteria and darkening below. On March 28, 1972, 27 *Thalassia* clumps were transplanted in Plot III-1 in one row in a north to south direction. The first ten of these plants never became completely dry. The remainder became dry at a spring low tide or had a considerable part of their leaves floating on the sea surface (Figure 10). On April 7, 1972, 13 *Thalassia* plánts were transplanted in Plot III-2 in continuation of Plot III-1. Spring low tide would expose all but the three southernmost plants. Plants in Plots III-1 and III-2 were planted 30 cm apart.

Plot IV-1 (Figures 7 and 8) was located approximately 199 m north of Plot II-1 and 20 m from mean high water line in a depth of approximately 0.9 m. Substrate was similar to that of Plot II-1. Wave action was also similar, with more boat traffic and more exposure to northeast winds. On July 11 and 12, 1972, 20 *Thalassia* clumps were transplanted into Plot IV-1 in four rows 46 cm apart, of five clumps each, 30 cm apart.

Plots V-1 and V-2 (Figures 7 and 8) were located on the north shore of the Bayway, 0.6 km west from the west corner of Point Brittany, in Boca Ciega Bay, 15 m from mean high water line, with a water depth of 1.2 m at mean low tide. Substrate was white sand and shell, similar to Plots II-1 and IV-1. Wave action was heavy from winds in a quandrant west-northwest to east and from some boat traffic. On July 25, 1972, ten clumps of *Thalassia* in two rows, 46 cm apart, of five clumps each, 30 cm apart, were transplanted in Plot V-1 in an east to west direction. On August 15, 1972, ten clumps of *Thalassia* were transplanted in Plot V-2 in two rows, 46 cm apart, of five clumps each, 30 cm apart, in an east to west direction. It was the intent to have Plot V-2 planted 30 cm south of Plot V-1 to form together four rows of five clumps. However, on the day of transplanting into Plot V-2, the exact location of Plot V-1 could not be found. Transplanting was done in the estimated vicinity of Plot V-1. When the plants were dug up on September 25, 1973, only one of the two plots could be relocated. On January 17, 1974, both plots were relocated during

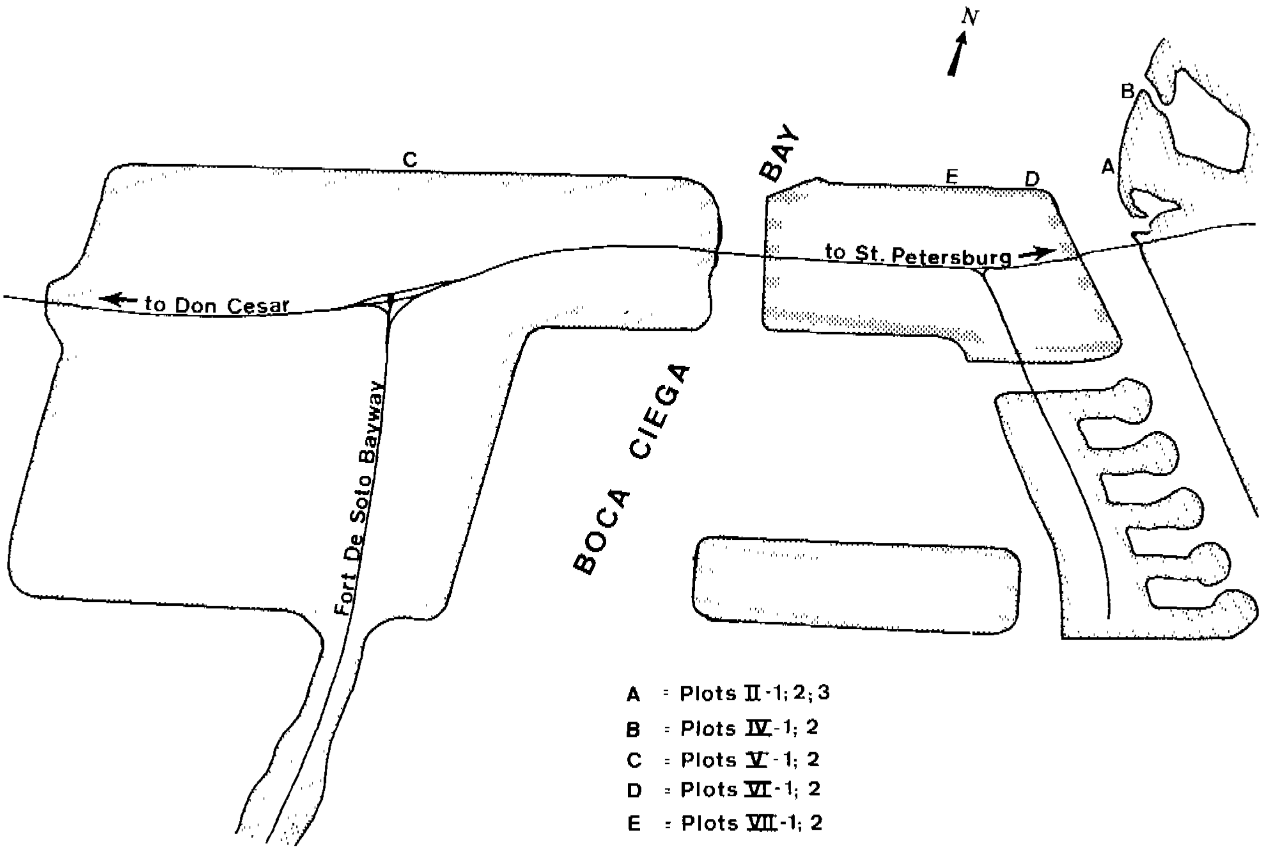

Figure 7. Cats Point, St. Petersburg, Florida.

a very low spring tide with Plot V-1 approximately 3 m north of Plot V-2.

Plot VI-1 (Figures 7 and 8) was located on the north shore of the Bayway in Boca Ciega Bay, 11 m from mean high water line in 0.9 m of water at mean low tide. Substrate was the same as at Plots II-1, IV-1 and V-1 in Boca Ciega Bay. Wave action was similar to Plot V-1, but more sheltered from east winds. On July 27, 1972, 20 *Thalassia* clumps were transplanted in Plot VI-1 30 cm apart in four rows, 46 cm apart, of five clumps each, in an east to west direction.

Plot VII-1 (Figures 7 and 8) was located on the north shore of the Bayway, 120 m west from Plot VI-1, 21 m from mean high water line in 0.9 m depth at mean low tide. Substrate was similar to the other plots in Boca Ciega Bay and wave action was comparable to Plot VI-1, but with less protection from east winds. On August 1 and 2, 1972, 20 clumps of *Thalassia* were transplanted in Plot VII-1 in four rows, 46 cm apart, of five clumps each, 30 cm apart and in an east to west direction.

Plots VIII-1 and VIII-2 (Figures 6, 8 and 9) were located on the east side of a *Thalassia* bed, approximately 5 m east from Plot III-1. Substrate was medium soft mud to more than 30 cm depth. It was unprotected from wave action from northeast to southeast winds. Shallow water of 0.6 m at mean low tide extended for approximately 18 m before it became deeper. On August 3 and 9, 1972, 30 *Thalassia* clumps were transplanted in Plots VIII-1 and VIII-2 in three rows of ten clumps in a north to east direction. Rows and clumps were 15 cm apart.

Plot IX-1 was located 3 m southeast of Plot VIII (Figures 6 and 9). Substrate was hard, whitish sand to approximately 10 cm, below which it became softer and darker. Wave action was as in Plot VIII. On September 29, 1972, 11 *Thalassia* clumps were transplanted approximately 2.5 m apart, scattered within a circle of 12 m in diameter. Depth at mean low tide was 0.6 to 0.9 m.

Plot X-1 (Figures 6 and 9) was located approximately 19 m south-southeast of Plot VIII and had a substrate and wave action similar to Plot IX. On October 27, 1972, ten clumps of *Thalassia* were transplanted into Plot X in one row, 76 cm apart in

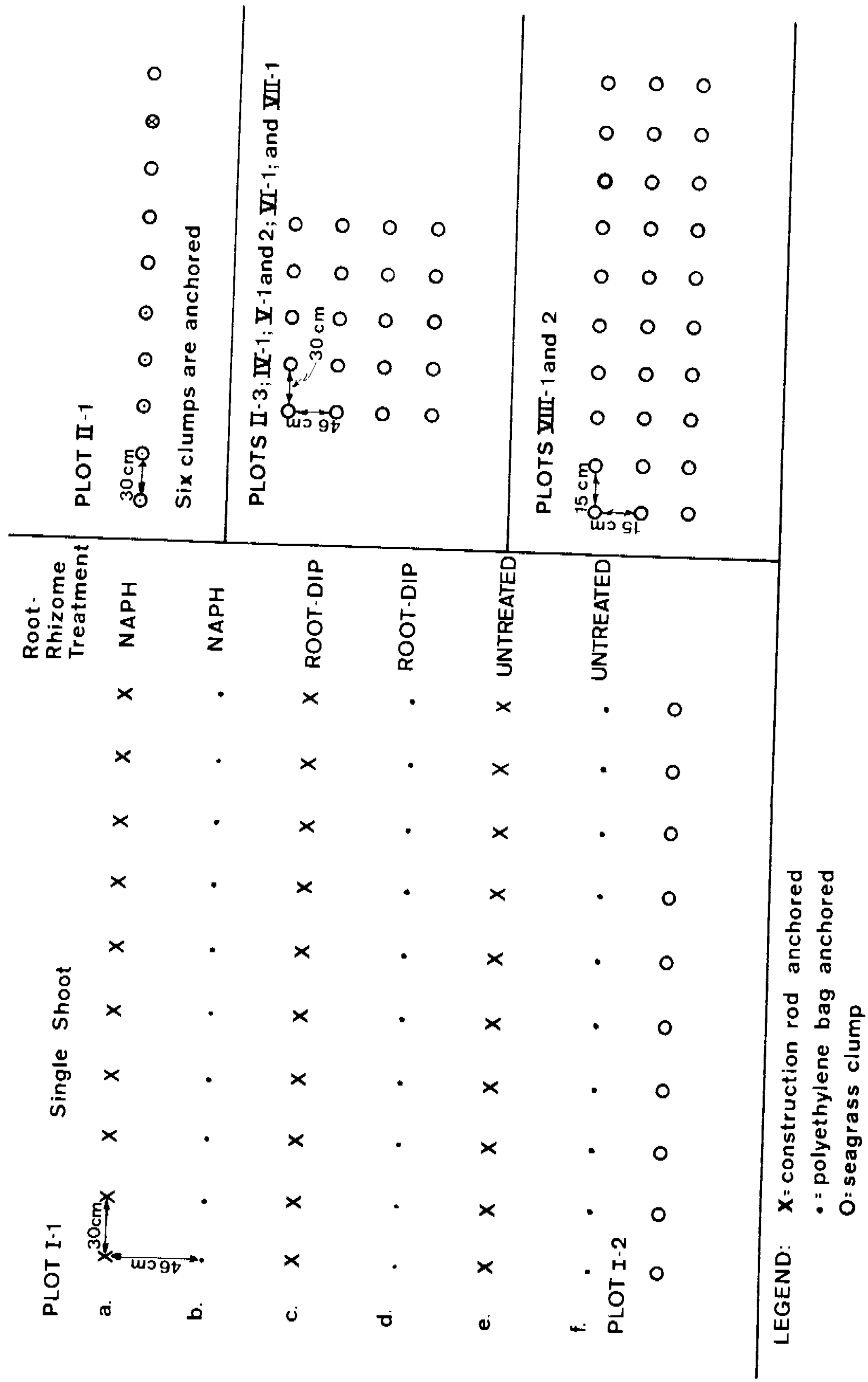

Figure 8. Selected seagrass transplant plot schematics.

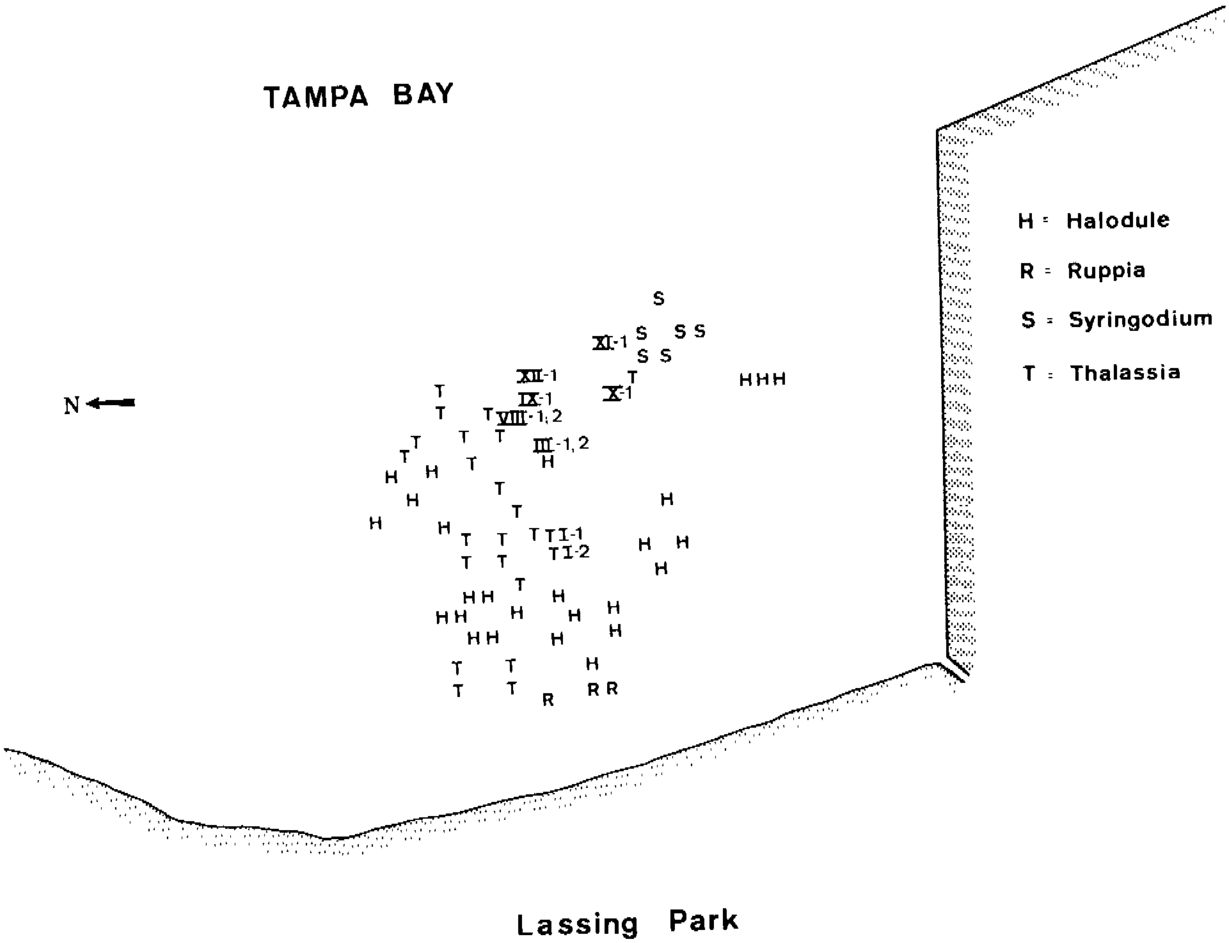

Figure 9. Location of plots at Lassing Park.

a depth of 0.6 to 0.9 m at mean low tide in a north to south direction, joining a *Thalassia* bed at the south side.

Plot XI-1 (Figures 6 and 9) was located approximately 19 m east of Plot X, with similar substrate and wave action as Plots IX and X and at the same depth of 0.6 to 0.9 m at mean low tide. On November 14, 1972, ten clumps of *Syringodium* were transplanted into Plot XI in one row, 76 cm apart, in a south-southeast to north-northwest direction, joining a *Syringodium* bed at the south end.

Plot XII-1 (Figures 6 and 9) was located approximately 5 m east of Plot X and with a similar substrate, wave action and depth. On December 6, 1972, five clumps of *Thalassia* and five clumps of *Syringodium* were alternately transplanted 76 cm apart in one row. Planting was in a north-northeast to south-southwest direction, starting with *Thalassia* at the north-northeast end.

Figure 10. Plots III-1 and 2 showing *Thalassia* leaves on surface of water.

TABLE 2. GROWTH SURVEYS OF PLOTS I-1 AND I-2
Plots I-1, *Thalassia* sprigs transplanted 2-29-72:
Row a) 10 shoots, NAPH treated, construction rod anchoring
Row b) 10 shoots, NAPH treated, polyethylene bag anchoring
Row c) 10 shoots, Root Dip treated, construction rod anchoring
Row d) 10 shoots, Root Dip treated, polyethylene bag anchoring
Row e) 10 shoots, untreated, construction rod anchoring
Row f) 10 shoots, untreated, polyethylene bag anchoring
Plot I-2 10 *Thalassia* clumps unanchored, transplanted 3-2-72

		1972						1973		Removal
DATE		3-20 3-23	4-7	4-22	6-2	6-27 7-18	8-8 8-15 9-14	2-8	5-22	9-14
PERCENTAGE SURVIVAL	I-1									
	Row a	80Y♦	0	10G▲	10G	10G	10G•★	10G	?G	20G▲
	Row b	60Y♦	0	0	0	0	0	0	?G	0
	Row c	100Y	100Y	90Y	60Y	60Y	60Y•★	50Y	?G	40G
	Row d	100Y	100Y	90Y	60Y	50Y	50Y•★	40Y	?G	20G
	Row e	100G	100*†	90Y	80Y	80Y	80*•★	60*	?G	100G▲
	Row f	90G	90*†	90Y	60Y	60Y	60*•★	60*	?G	20G
	I-2	100G	100G°	100G°	100G°	100G°	100G•★	100G	?G	100G†
CONDITIONS							very low tide			very low tide
SURVEY								relocation difficult	relocation difficult	
PRESENCE OF DRIFT ALGAE								*Ulva*	*Hypnea*	

G - green leaves; Y - yellowing leaves; * - fair condition; † - good condition; ° - excellent cond.; ♦ - poor condition; ▲ - reappearance of leaves; ★ - exposed to air; • - floating leaves

RESULTS AND DISCUSSION

A check on June 2, 1972, was made of the *Thalassia* beds from which transplants were obtained. All holes made with the posthole digger had filled and were overgrown.

PLOT I-1 AND I-2 (TABLE 2)

On September 14, 1973, representative samples were removed from Plots I-1 and I-2, 563 and 565 days, respectively, after transplanting, with the following results:

Plot I-1:

Row a: Of the 10 shoots treated with NAPH and anchored with construction rods, only two survived. On one plant, one rhizome was 10 cm and another rhizome without apex was 11 cm (Figure 11). On the other plant, the rhizome was 25 cm long (Figure 12a). These measurements were taken from the place of the original shoot or clump to the tip of the rhizome.

Row b: Of the 10 single shoots treated with NAPH and anchored in polyethylene bags, none survived.

Row c: Of the 10 shoots treated with Root-Dip and anchored with construction rods, four survived and two removed samples showed rhizomes of 28 and 53 cm length (Figure 12c).

Row d: Of the 10 single shoots treated with Root-Dip and anchored with polyethylene bags, only two survived. One sampled plant showed a rhizome 10 cm long coming out of the polyethylene bag (Figure 13d).

Row e: Of the 10 single shoots anchored with construction rods and not treated, all ten survived, although on the previous checkup in February, only six could be found. Two plants were removed, one plant had a rhizome of 23 cm length while the other plant had three rhizomes of 12, 21.5 (broken off apex), and 24 cm (Figure 14).

Row f: Of the 10 single shoots not treated and anchored with polyethylene bags, only two survived. A sampled plant showed the rhizome in a peculiar U-shape, apparently caused by the polyethylene bag (Figures

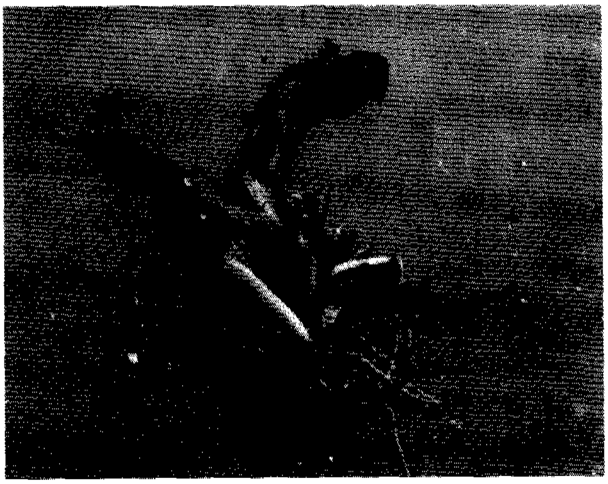

Figure 11. Plot I-1: row a): rhizome growth of *Thalassia* sprig anchored with rod and treated with NAPH.

Figure 13. Plot I-1: row d): rhizome growth of *Thalassia* sprig anchored with polyethylene bag and treated with Root Dip. row f): rhizome growth of *Thalassia* sprig anchored with polyethylene bag and untreated.

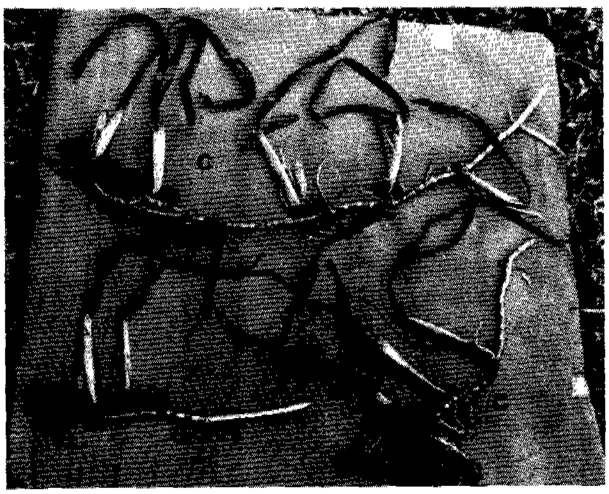

Figure 12. Plot I-1: row a): rhizome growth of *Thalassia* sprig anchored with rod and treated with NAPH. row c): rhizome growth of *Thalassia* sprig anchored with rod and treated with Root Dip.

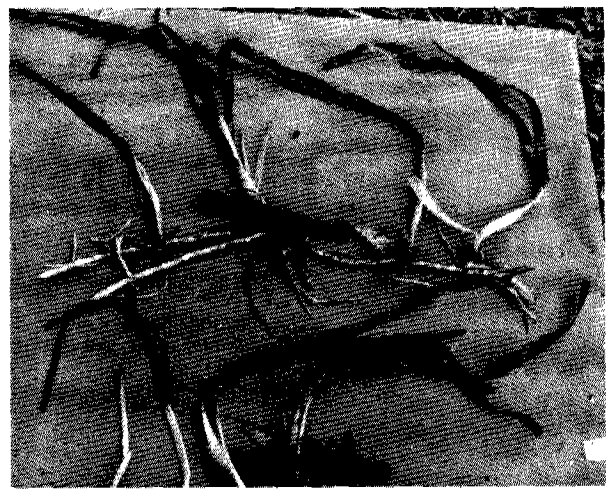

Figure 14. Plot I-1: row e): rhizome growth of *Thalassia* sprig anchored with rods and untreated.

13f and 15). Total length of the U-shape rhizome was 25 cm.

Of the ten clumps in Plot I-2, all survived with good growth. A sampled plant showed one rhizome of 21.5 cm and another of 67 cm length (Figure 16).

Survival rates in Plot I-1 demonstrate that rods are preferable over polyethylene bags as an anchoring device, and that use of hormones on rhizome apices does not give an advantage over untreated plants. Use of 5% NAPH seemingly resulted within 6 weeks in 90% mortality when a sprig was anchored with a rod and 100% mortality when an-

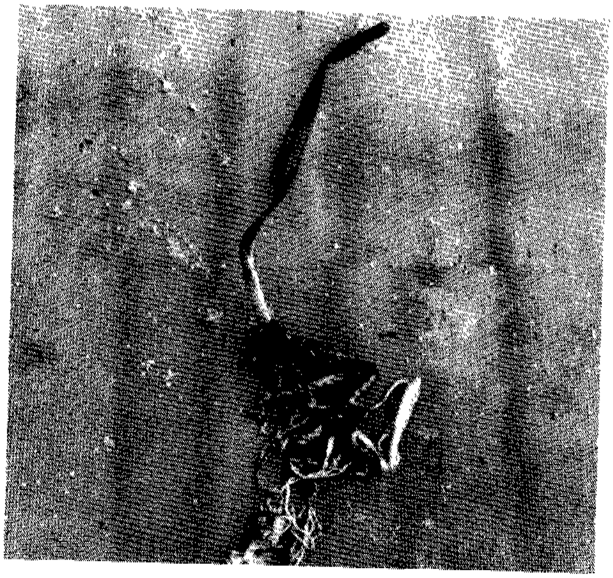

Figure 15. Plot I-1: row f): close up of U-shaped rhizome of Figure 13, row f.

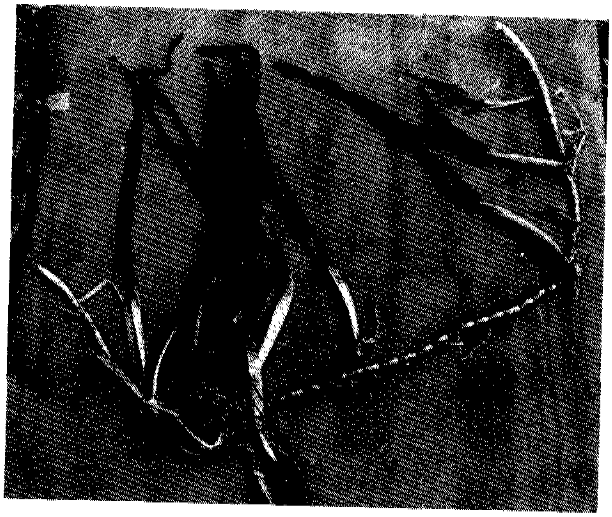

Figure 16. Plot I-2: rhizome growth of unanchored *Thalassia* clump.

chored with a polyethylene bag. Root-Dip which has 0.05% NAPH did not appear to have such a drastic effect on the apices, and a higher survival rate was obtained. Additionally, rhizomes of these surviving plants were longer than those of plants treated with NAPH (Figure 12). Also, the laboratory tests started on January 17, 1972, in which apices of plants were dipped in 10% NAPH as recommended by Kelly et al. (1971), resulted in 100% mortality on March 20, 1972. Untreated plants in the same aquaria were still alive and growing. Consequently, the use of NAPH in a 5% or 10% concentration is not recommended.

Untreated sprigs in row e anchored with rods had a 100% survival rate, and those anchored with polyethylene bags in row f had only 20%. Polyethylene bags may have prevented rhizomes from developing naturally as illustrated by the U-shaped rhizome in Figures 13f and 15. However, this abnormality was a single observation. The 100% survival of the single untreated sprigs anchored with construction rods may be attributed not only to little wave action at the location, but also to the favorable anaerobic sediment condition. The black coating on the used rods pointed either to black, relatively insoluble FeS formed under anaerobic conditions, or to the black, unstable FeO, indicating an anaerobic or reduced condition. Black FeO would oxidize to red Fe_2O_3 in aerobic or oxidized conditions (Quagliano, 1963).

In Plot I-2, the method of transplanting whole clumps was used for the first time. Besides little wave action and favorable sediment, the transfer of the sediment around the roots and rhizomes without overexposure of the rhizome/root system to air must have contributed to a 100% survival. Additionally, in Plots I-1 and I-2 transplants were made during cooler water temperatures or 21.0-21.5°C (Table 3) which continued for six weeks, giving the plants opportunity to stabilize without excessive growth. It was not until after seven weeks that the temperature increased to 25.5°C, reaching the maximum of 28.0°C on June 27, 1972. Notwithstanding these favorable conditions and substrate, a high mortality occurred in the second month among the sprigs treated with NAPH. The mortality of sprigs treated with Root-Dip and of untreated sprigs anchored with polyethylene bags was highest (30%) from April 22 to June 2, 1972. During this time, temperature increased from 25.5°C to 27.5°C, with a salinity low of 24.7 ‰ on April 21, 1972. During this period, untreated sprigs anchored with rods had an apparent mortality of only 10%. Hormones and increased temperatures may have induced an excessive growth not maintainable by the plant, while polyethylene bags may have physically restricted the plants during this growth period.

Tomlinson and Vargo (1966) stated that short shoots (blade portions of the plant) develop at wide but regular intervals on the long shoots (rhizomes). Generally, this was not the case in my experiments (see Figures 12a, c and 16). These so-called irregularities could be the effect of transplanting. However, Patriquin (1973) also found short shoot formations at irregular intervals in natural *Thalassia* beds.

TABLE 3. WATER TEMPERATURES AND SALINITIES FOR ORIGINAL PLANT LOCATIONS (MAXIMO POINT AND SECOND TOLL BRIDGE) AND TRANSPLANT SITES (LASSING PARK AND CATS POINT).

LASSING PARK			CATS POINT			MAXIMO POINT	
	Temp. C°	Salinity 0/00		Temp. C°	Salinity 0/00	Temp. C°	Salinity 0/00
1972			1972			1972	
Feb. 29	21.5	29.08	March 21	22.0	33.93	21.0	31.31
March 22/23	21.0	25.85	April 6	23.0	31.23		
March 28	21.0	26.92	April 11	23.0	32.31	22.0	32.31
April 7	21.5	26.38	April 21	27.0	32.31		
April 12	22.0	28.0	April 25	28.0	32.31	28.0	32.31
April 21	25.5	24.7	April 26	28.0	32.31		
June 2	27.5	26.92	May 12	27.5	32.85	2ND TOLL BRIDGE	
June 27	28.0	29.08	May 19	27.5	32.31	Temp. C°	Sal. 0/00
July 11	27.5	26.92	May 26	26.5	32.31	24.0	32.31
Oct. 27	27.0	30.69	June 1	28.0	32.31		
Nov. 14	23.0	30.15	June 26	27.5	32.31		
Dec. 12	23.5	30.15	July 11	28.5	33.93	27.0	33.39
1973			July 27	28.0	33.39	28.0	33.93
Feb. 8	17.0	29.08	Nov. 9	23.5	33.39		
May 22	27.0	27.46	Dec. 14	24.3	33.39		
Sept. 14	27.3	29.62	1973				
			Feb. 9	17.0	32.31		
			March 20	19.5	33.39		
			March 27	20.0	33.39		
			June 27	28.0	33.93		
			Sept. 17	28.0	33.39		

The number of developed rhizomes varied without an identifiable pattern. In Figure 14, a rod-anchored sprig showed three rhizomes, while a clump in the same area (Plot I-2) formed two rhizomes (Figure 16). A clump in Plot II-2, in unfavorable sediment conditions but transplanted close to another clump, had seven rhizomes. There seemed to be a tendency for formation of three or more rhizomes when the clumps were planted close together.

The closeness of the clumps may have allowed newly formed rhizomes to grow from one favorable sediment to another favorable sediment. A personal observation (SCUBA) was made on June 18, 1974, five years and seven months after *Thalassia* had been scoured from an area in Tampa Bay with a hydraulic clam dredge (Godcharles, 1971). The denuded area was covered by a fine sand to a depth of more than 40 cm. This can be considered very unfavorable for *Thalassia*. In the middle of the area, several older *Thalassia* plants which had not been uprooted by the dredge were growing. Their rhizomes were closely confined to the area surrounding these plants and did not extend into the denuded area. Rhizomes of the plants surrounding the denuded area grew parallel to the fringe and not into the unfavorable fine sand. Observationally, this demonstrates clearly the sediment selectivity of the rhizomes in their growth pattern.

A natural denudation by sea urchins, *Lytechinus variegatus*, of *Thalassia* beds occurred at Steinhatchee, Florida (Camp et al., 1971). As reported, the remaining *Thalassia* rhizomes in the denuded areas were in various stages of decay. Three years later, on October 31, 1974, observation disclosed that siltation had been continuous and had formed a five to eight cm upper layer of fine sand and shells. A distinct pattern of recolonization was observed; first, the fringe of a remaining *Thalassia* bed, followed by a small strip of *Halodule*, then a large strip of denuded area followed by a heavy growth of *Halodule*, again followed by a large strip of denuded area, a small strip of *Halodule* and the original *Thalassia* bed, in that order. Most likely, due to siltation, aerobic conditions prevailed and *Halodule* had taken over.

PLOTS II-1, II-2, II-3, AND IV-1 (TABLE 4)

On September 17, 1973, 546 days after transplanting in Plot II-1, a count was made and representative samples were removed with the following results.

Of the five clumps anchored with polyethylene bags, three survived; of the two removed clumps, one had rhizomes 5 cm and 17.8 cm long, and the

TABLE 4. GROWTH SURVEYS OF PLOTS II-1, II-2, II-3, AND IV-1.

Plot II-1. *Thalassia* clumps transplanted in a single row 3-21-72, Part 1) 5 clumps anchored with polyethylene bags, Part 2a) 4 clumps unanchored, Part 2b) 1 clump anchored with construction rod.
Plot II-2. *Thalassia* clumps transplanted 4-25-72, 10 clumps unanchored in 1 row.
Plot II-3. *Thalassia* clumps transplanted 5-25/26-72, 20 clumps unanchored in 4 rows of 5 clumps.
Plot IV-1. *Thalassia* clumps transplanted 7-11-72, 20 clumps unanchored in 4 rows of 5 clumps.

		1972									1973	Removal
DATE		3-24	4-6 4-21 4-25	4-26	5-12 5-19 5-25	6-1 6-15 6-19	7-6 7-21	9-7 10-12	11-10	12-14-72 2-9-73	3-27	II-1, 9-17 II-2, 9-25 II-3, 9-17 IV-1, 9-17
PCT. SURV.	II-1 Part 1	100G	100G	100G	80G	80G	60G†	60GB	60GB	60GB	80G▲	60G
	Part 2a	100Y	100G	100G	100G	100G	100G†	100GB	100GB	75GB	75G	100G
	Part 2b	100Y	100G	100G	100G	100G	100G†	100GB	100GB	100GB	100G	100G
	II-2	—	—	100G	—	—	40G†	50GB▲	40GB	20GB	20G▲	30G
	II-3	—	—	—	100G	100G	70G†	75GB▲	75GB	75GB	65G	60G
	IV-1	—	—	—	—	—	100G	100GB	85GB	75GB	—	65G
COND.				heavy storm evening before			turbid water high tide				tide too high to relocate IV-1	
SURVEY							relo-cation difficult			relo-cation difficult	relo-cation difficult	
INV. OF OTHER SEAGR.								*Halodule* in IV-1	*Halodule* in IV-1	*Halodule* in IV-1	*Halodule* in IV-1	*Halodule* in IV-1
PRES. OF DRIFT ALGAE										*Giffordia*		

G - green leaves
B - brown leaves' tips
Y - yellowing leaves
† - more growth
▲ - reappearance of leaves

other a rhizome 8 cm long (Figure 17). All four of the unanchored plants and the one anchored with a construction rod survived. A removed unanchored clump showed 2 rhizomes of 23 cm and 6.5 cm length (Figure 18).

On September 25, 1973, 519 days after transplanting, 3 out of 10 unanchored clumps survived in Plot II-2, and a removed clump showed three rhizomes 40.6 cm, 40.6 cm, and 12.7 cm long (Figure 19). Most of this plot was overgrown by *Halodule wrightii*.

On September 17, 1973, 481 days after transplanting, 12 out of 20 clumps in Plot II-3 survived and a representative sample of one clump showed four rhizomes of 49.5 cm, 36.8 cm, 38.1 cm, and 30.5 cm length (Figure 20).

On September 17, 1973, 433 days after transplanting in Plot IV-1, 13 out of 20 clumps survived. One removed clump showed seven rhizomes of 34.1 cm, 15.2 cm, 14.0 cm, 35.6 cm, 40.6 cm, 10.2 cm, and 29.2 cm length (Figure 21). The plot was overgrown with *Halodule wrightii*, and approximately 2.6 m from the plot, beds of *Halodule wrightii* had newly formed (Figure 22). The *Halodule* may have been brought over with the transplanted *Thalassia* clumps, because no *Halodule* beds were observed in the area before the transplantings.

Figure 17. Plot II-1: rhizome growth of *Thalassia* clump anchored with polyethylene bag.

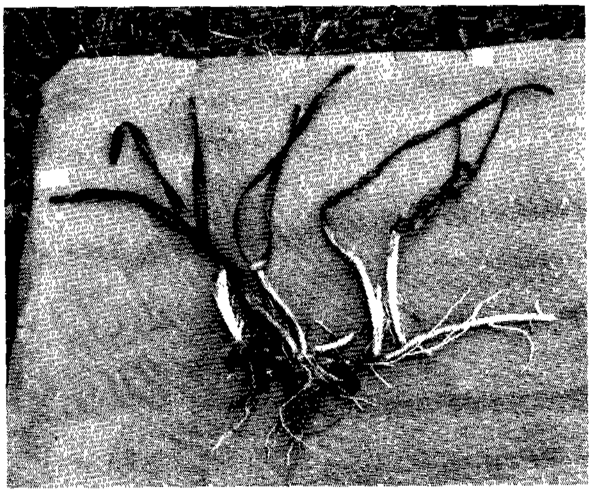

Figure 18. Plot II-1: rhizome growth of unanchored *Thalassia* clump.

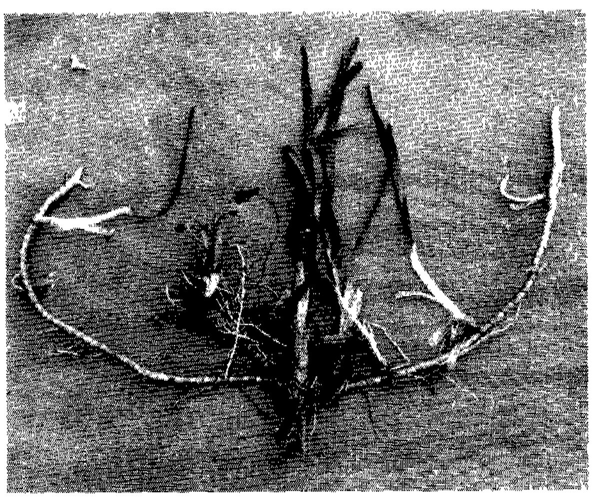

Figure 19. Plot II-2: rhizome growth of unanchored *Thalassia* clump.

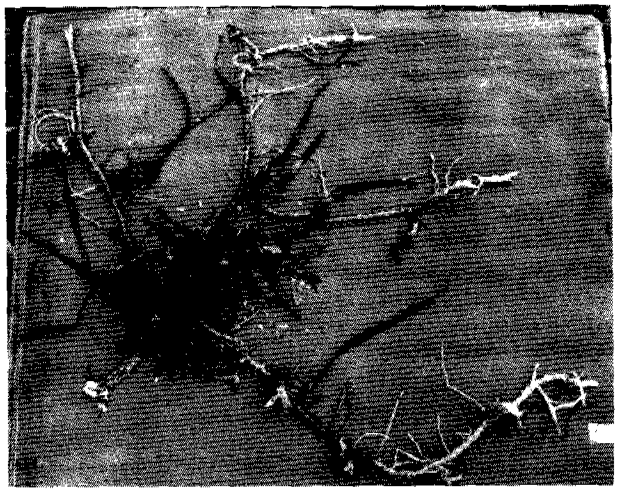

Figure 20. Plot II-3: rhizome growth of unanchored *Thalassia* clump.

Figure 21. Plot IV-1: rhizome growth of unanchored *Thalassia* clump.

Although survival rate of the clumps anchored with polyethylene bags in Plot II-1 was 60%, Figure 17 shows that after 546 days, growth and development of new shoots was barely noticeable whereas unanchored clumps had 2 shoots with long leaves and a healthy rhizome (Figure 18). This was also observed with unanchored clumps in Plot II-2 (Figure 19). These clumps were planted in one row, 30.48 cm apart, in a very high energy location, and the survival rate was only 30%. Survival rates in Plots II-3 and IV-1 were at least twice as high, respectively 60% and 65%. High energy wave action in these plots was the same or more than in Plot II-2, but the clumps were transplanted in four rows of five clumps each, thereby offering self-protection against wave action within rows and a closer association of the original transferred sediment within the plot.

Highest mortality in Plot II-2 was 40% between June 15 and July 6, 1972. Temperature during that period did not vary, thus eliminating this parame-

Figure 22. Cats Point: aerial view of Plots II and IV with spreading *Halodule* patches.

ter as a cause. However, Hurricane Agnes, which struck on June 19, 1972, could have been the cause of this 40% mortality, as well as the 30% mortality in Plot II-3, although the latter was expected to be more resistant to disturbance because the clumps were in 4 rows and were close together. Plot II-1 was transplanted one month before Plot II-2 and two months before Plot II-3 and perhaps was better established and more resistant to Agnes' force. At the end of the experiment, natural *Halodule* beds had covered some of the area near Plot II-3 and in Plot IV-1 (Figure 22), indicating an unfavorable sediment for *Thalassia*. However, Figures 20 and 21 show healthy plants in these plots which could be due to the transferred sediment.

PLOTS III-1 AND III-2 (TABLE 5)

On September 25, 1973, 546 and 536 days, respectively, after transplanting Plots III-1 and III-2, a final count was made with the following results: 10 out of 27 clumps survived in Plot III-1. These were the northernmost 10 clumps which were not exposed or only slightly exposed at very low tides. They were overgrown with *Halodule wrightii*. The last two plants of III-2 survived under similar growing conditions as the survivals in Plot III-1. Those lost were frequently and severely exposed to air (Figure 10) and gradually died. Highest mortalities in Plots III-1 and III-2 were 55% and 63%, respectively, during winter months, with colder temperatures affecting clumps which had been regularly exposed to the air during low tides.

A clump removed from Plot III-1 had three rhizomes, 40.6 cm, 45.7 cm, and 34.3 cm long (Figure 23a). This sample from the first 10 clumps showed healthy growth with many new shoots. These 10 plants were growing in the deepest spot of these plots and were also adjacent to *Thalassia* beds, but became overgrown by *Halodule*, indicating an aerobic substrate. Good growth could be the result of the initial transfer of substrate, possibly aided by spotty anaerobic conditions of the adjacent *Thalassia* beds.

After 546 days, one of the two surviving clumps (Figure 23b) in Plot III-2 had one short rhizome of 12.7 cm and no development of short shoots. This rhizome growth is far below the average of 20 cm annually, mentioned by Tomlinson (1966). These

TABLE 5. GROWTH SURVEYS OF PLOTS III-1 AND III-2

Plot III-1. *Thalassia* clumps transplanted 3-28-72, unanchored, 27 clumps in row.
Plot III-2. *Thalassia* clumps transplanted 3-28-72, unanchored, 13 clumps in row in continuation of III-1.

	1972						1973		Removal
DATE	6-27	7-13 7-19	8-3 8-9	8-16	10-11 12-6	12-20	2-8	5-22	9-25
PERCENTAGE SURVIVAL III-1	95G	100G♦	100G•★	85B•★	85B*•★	30B†	82 avg.	28 avg.	37G
PERCENTAGE SURVIVAL III-2	—	100G♦	100G•★	100B•★	85B*•★	22	B▲†♦▼	†♦	15G
CONDITIONS			very low tide	very low tide	very low tide				very low tide
SURVEY						relocation difficult			
INVASION OF OTHER SEAGRASSES					*Halodule* first 8 clumps	*Halodule* first 8 clumps	*Halodule* first 10, last 3 clumps	*Halodule* first 10, last 3 clumps	*Halodule* first 10, last 3 clumps
PRESENCE OF DRIFT ALGAE							*Enteromorpha*	*Hypnea*	

G - green leaves; • - floating leaves; B - brown leaves' tips; † - small leaves; ♦ - poor condition; ▼ - new growth; ★ - exposed to air; * - fair condition; ▲ - reappearance of leaves.

clumps were on a sandbar and not close to any grass beds. They were strictly dependent upon transferred sediment for growth in an unfavorable aerobic area and upon submergence for survival. This area was also overgrown by *Halodule* at the end of the experiment.

PLOTS V-1 AND V-2 (TABLE 6)

The two plots could never be relocated at the same time until January 16, 1974. On September 20, 1973, 401 days after transplanting in Plot V-2, only two of 10 clumps survived. One removed plant showed three rhizomes of 50.8 cm, 40.6 cm, and 25.4 cm length (Figure 24). On January 16, 1974, 540 days after transplanting, only 2 out of 10 clumps survived in Plot V-1. A removed clump showed three rhizomes of 9.0 cm, 3.8 cm, and 2.5 cm length (Figure 25).

Compared to other plots, Plots V-1 and V-2 had heavier wave action and deeper, more turbid water, which could have been the cause for only 20% survival. Also, the arrangement of planting in two rows of five clumps instead of four rows of five clumps did not provide self-protection against wave action. Even so, the surviving transplants in Plot V-2 showed vigorous growth of rhizomes and new shoots after 401 days (Figure 24). The clump from Plot V-1 (Figure 25), in deeper water than Plot V-2, showed only two rhizomes. It must be mentioned that this clump was dug out in January, during which time little growth occurred and old growth had died off.

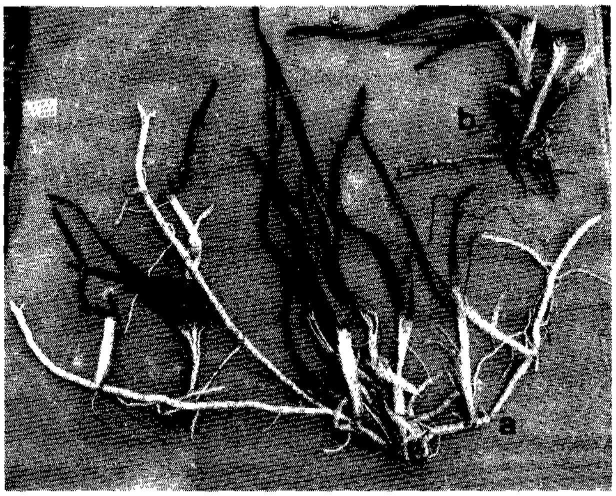

Figure 23. Plot III-1: a) rhizome growth of unanchored *Thalassia* clump. Plot III-2: b) rhizome growth of unanchored *Thalassia* clump.

PLOTS VI-1 AND VII-1 (TABLE 7)

On September 17, 1973, 416 days after transplanting Plot VI-1, 10 out of 20 clumps were alive. One removed representative clump showed seven rhizomes of 56.0 cm, 48.3 cm, 15.2 cm, 13.8 cm, 35.6 cm, 29.2 cm, and 33.0 cm (Figure 26). On September 17, 1973, 411 days after transplanting Plot

TABLE 6. GROWTH SURVEYS OF PLOTS V-1 AND V-2
Plot V-1. *Thalassia* clumps transplanted 7-25-72, unanchored, 10 clumps in 2 rows of 5 clumps.
Plot V-2. *Thalassia* clumps transplanted 8-15-72, unanchored, 10 clumps in 2 rows of 5 clumps.

		1972			Removal	Removal
DATE		8-7	9-7	10-17	9-20-73	1-16-74
PERCENTAGE SURVIVAL	V-1	100G	10 clumps-not known from which Plot-G	10 clumps-not known from which Plot-G	—	20G
	V-2	—			20G	—
CONDITIONS			high tide and winds	high tide and winds		
SURVEY			reloca-tion difficult	reloca-tion difficult		
INVASION OF OTHER SEAGRASSES					some *Halodule*	some *Halodule*

G - green leaves

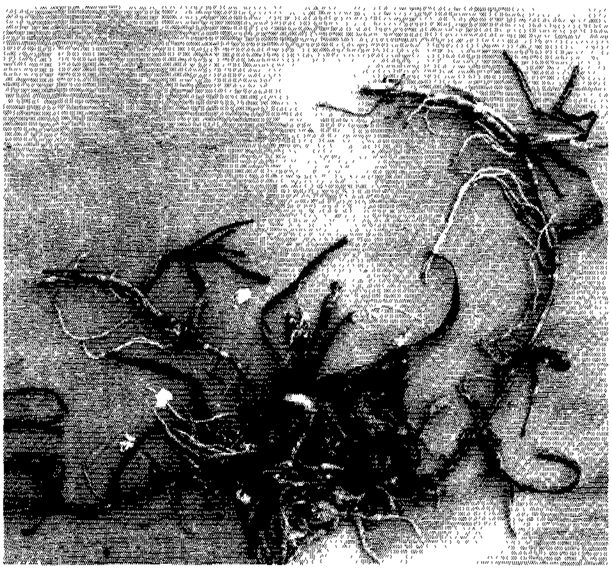

Figure 24. Plot V-2: rhizome growth of unanchored *Thalassia* clump.

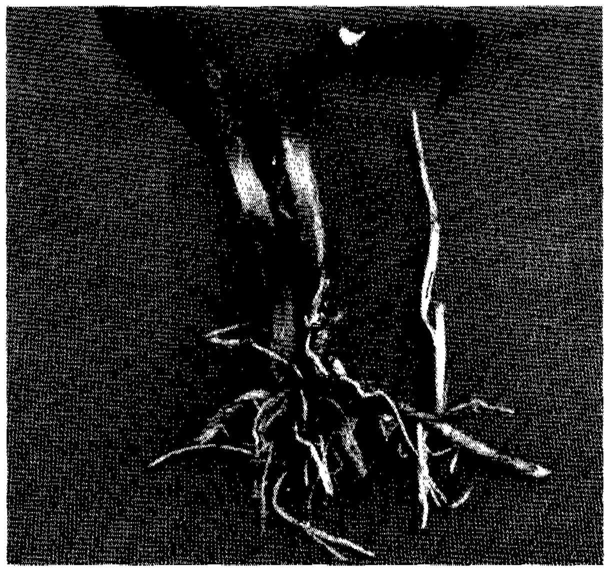

Figure 25. Plot V-1: rhizome growth of unanchored *Thalassia* clump.

VII-1, 10 out of 20 clumps survived and one removed sample showed three rhizomes of 30.5 cm, 96.5 cm and 10.2 cm length (Figure 27).

Figure 26 shows a vigorous clump with seven rhizomes and many new short shoots after 416 days in Plot VI-1. Figure 27 shows a healthy plant after 416 days in Plot VII-1. Clumps in both plots were planted in four rows of five clumps, thus providing self-protection for the inside plants and a closer sediment transfer. The highest mortality of 45% in Plot VI-1 occurred between December and April, while the decline in survival in Plot VII-1 was gradual during the experiment.

All plots at Cats Point were an unfavorable aerobic environment for *Thalassia*, which was clearly indicated by newly formed beds of *Halodule* (Figures 22 and 28). This area, before the dredging of the Bayway and Point Brittany (Figures 1 and 2), had large *Thalassia* beds (Phillips, 1960) but was changed from an anaerobic into an aerobic condition by dredgings resulting in a top layer of at least 18 cm of fine white sand and shell.

Water temperatures and salinities at Cats Point from the first transplanting on March 21, 1972, followed a regular seasonal pattern (Table 3). Water temperatures at the location where the clumps

TABLE 7. GROWTH SURVEYS OF PLOTS VI-1 AND VII-1.
Plot VI-1. *Thalassia* clumps transplanted 7-28-72, unanchored, 4 rows of 5 clumps.
Plot VII-1. *Thalassia* clumps transplanted 8-1/2-72, unanchored, 4 rows of 5 clumps.

	1972					1973	Removal
DATE		8-2 9-7	10-13	11-9	12-14	4-15	9-17
PERCENTAGE SURVIVAL	VI-1 VII-1	100G 100G	95G 95G	95G 80G	95GB▲ 75GB▲	50G 60G	50G 50G
CONDITIONS							very low tide
PRESENCE OF DRIFT ALGAE					*Giffordia*	*Enteromorpha*	

G - green leaves
B - brown leaves' tips
▲ - new growth

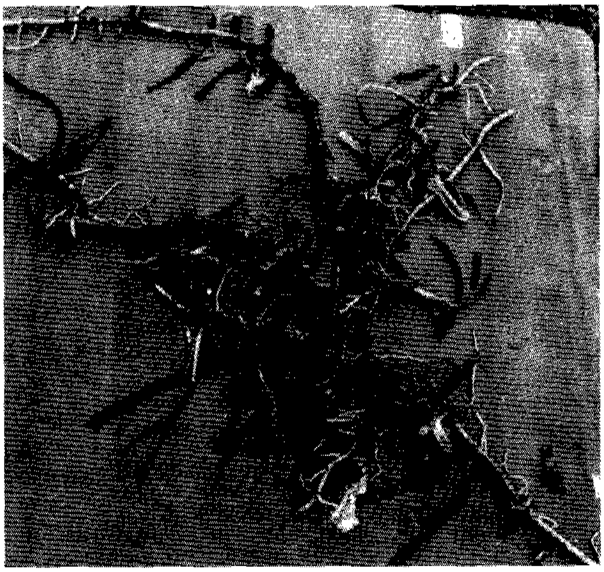

Figure 26. Plot VI-1: rhizome growth of unanchored *Thalassia* clump.

Figure 27. Plot VII-1: rhizome growth of unanchored *Thalassia* clump.

were obtained was equal or slightly higher than that of the transfer locations. The greatest difference was 2.5°C. Salinity varied from 2.62 ‰ lower to 0.54 ‰ higher. Damage, if any, caused by these differences or by the transportation over a distance of 2.5 km could not be evaluated.

PLOTS VIII-1 AND VIII-2 (TABLE 8)

A final count was made on September 17, 1973, 410 and 404 days, respectively, after transplanting Plot VIII-1 and Plot VIII-2. As of May 22, 1973, the clumps had spread out and a massive bed had formed. One representative clump was removed and showed five rhizomes of 55.9 cm, 17.8 cm, 10.2 cm, 12.7 cm, and 7.1 cm length (Figure 29).

Results from these plots, where 30 clumps were transplanted very close together in three rows of ten clumps each, demonstrate the advisability of "close" transplanting. The favorable substrate with the added "pack" of transferred sediment resulted in a new *Thalassia* bed that offered protection from wave action to each clump whether inside or at the periphery of the plot. After 404 days, the original clumps could barely be distinguished from the newly formed short shoots. Figure 29 shows a clump with five rhizomes and new short shoots. It is understandable that 30 similar clumps with criss-crossing rhizomes and roots were holding the sub-

Figure 28. Cats Point: aerial view of Plots VI and VII with spreading *Halodule* patches.

TABLE 8. GROWTH SURVEYS OF PLOTS VIII-1 AND VIII-2.
Plot VIII-1. *Thalassia* clumps transplanted 8-3-72, unanchored, 3 rows of 10 clumps very close together.
Plot VIII-2. *Thalassia* clumps transplanted 8-9-72, unanchored, 3 rows of 10 clumps very close together.

		1972			1973		Removal
DATE		8-16	10-11 12-6	12-20	2-8	5-22	9-17
PERCENTAGE SURVIVAL	VIII-1 VIII-2	100G 100G	94G 100G	77G** clumps very close together — difficult to count	83G▲** new, short shoots very close together	100 plus G▲ 62 plants counted — dense bed	100 plus G dense bed
PRESENCE OF DRIFT ALGAE						*Hypnea* adrift	

G - green leaves
** - good condition
▲ - reappearance of leaves

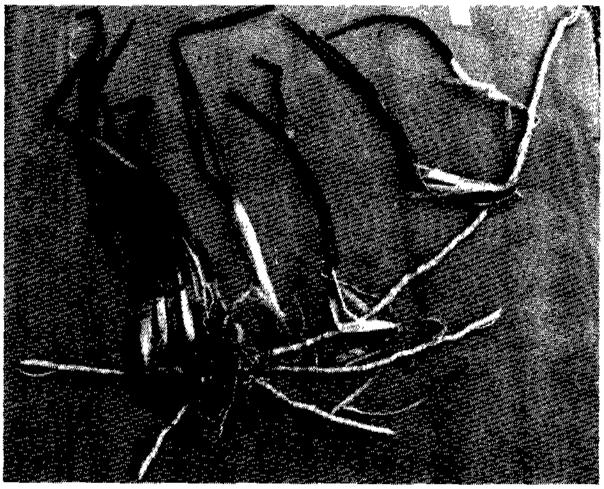

Figure 29. Plot VIII-1 and -2: rhizome growth of unanchored *Thalassia* clump.

strate together, which prevented the clumps from being washed away. During the winter months, some clumps temporarily died back. They recovered blade growth soon after, having a full growth again in May.

PLOTS IX-1 AND X-1 (TABLE 9)

On September 17, 1973, 353 days after transplanting Plot IX-1, only 3 out of 11 clumps were present. These clumps were removed; one did not have new rhizomes (Figure 30, upper left), a second had two rhizomes (Figure 30, right, and 31) of 2.5 cm and 5.1 cm length. The third clump showed one rhizome of 33.0 cm (Figure 30, center).

On September 17, 1973, 325 days after transplanting Plot X-1, all 10 remained. One of three representative clumps removed showed two rhizomes of 43.2 cm and 16.2 cm length and two rhizomes where the apices were broken off with 27.9 cm and 10.2 cm length (Figure 32). A second removed plant showed no new rhizome growth at all (Figure 33, right), but the leaves were still green and new ones were forming. The third removed clump showed only one rhizome of 7.6 cm (Figure 33, left).

Survival rate of Plot IX-1 (Table 9) after 353 days was only 27%. All factors were unfavorable: a generally aerobic substrate, no protection against waves, 2.5 m between clumps, and unfavorable temperature. Figure 30 shows three surviving clumps. One clump, upper left, shows no rhizome growth. The second, in the center, has one long rhizome and the third shows two rhizomes, which first grew upward then bent over to a slightly horizontal position, seemingly searching for more favorable substrate (Figure 31). All three clumps show three or more of the original clump shoots, suggesting the advantageous effect of transferred sediment for maintaining growth. The first and third clumps were unable to grow further due to unfavorable substrate, while the second produced a long shoot with two meager short shoots. The latter could be due to slightly varied substrate in this wide area.

Survival in Plot X-1 was 100% (Table 9) and green leaves prevailed during this experiment. Figure 32 shows a healthy original clump with four rhizomes and new shoot development. Figure 33 shows two original clumps, one of which had rhizome development. As in Plot IX-1, transfer of the sediment enabled the clumps to survive but unfavorable sediment environment seemed to prevent further growth. However, the clump of Figure 32 may have had favorable local conditions. Also, these clumps were transplanted at a temperature of 27.0° C on October 27, which soon dropped to 23.0°C and decreased to 17.0°C in February. During this low temperature period, the seagrasses were in a semidormant stage, allowing them to become stabilized before completely utilizing the

TABLE 9. GROWTH SURVEYS OF PLOTS IX-1 AND X-1.
Plot IX-1. *Thalassia* clumps transplanted 9-29-72, unanchored, 11 clumps scattered, 2.5m apart.
Plot X-1. *Thalassia* clumps transplanted 10-27-72, unanchored, 1 row of 10 clumps, 60cm apart.

		1972			1973			Removal
DATE		10-11	10-31	12-6	12-20	2-8	5-22	9-17
PERCENTAGE SURVIVAL	IX-1 X-1	100G —	73G 100G	73G 100G	64G* 100G*	55* 100**	27G 100G	27G 100G
PRESENCE OF DRIFT ALGAE							*Hypnea*	

G - green leaves
* - fair condition
** - good condition

Figure 30. Plot IX-1: rhizome growth of unanchored *Thalassia* clump.

Figure 32. Plot X-1: rhizome growth of unanchored *Thalassia* clump.

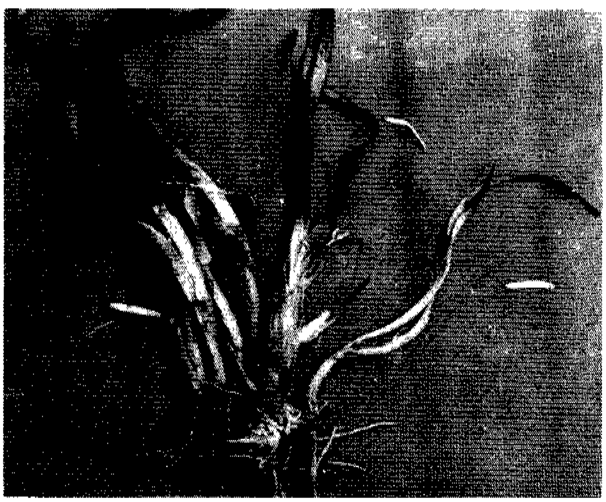

Figure 31. Plot IX-1: close up of rhizome growth of Figure 28.

Figure 33. Plot X-1: rhizome growth of unanchored *Thalassia* clumps.

nutrients in the transferred sediment.

Plot IX-1, however, was transplanted during optimum growth temperature of 27°C, which was maintained for at least six weeks. There was an initial 27% mortality, followed by another 18% mortality during the semidormant stage through February when temperatures dropped. As the temperature increased in the spring, there was an additional 28% loss. It is speculated that many of the nutrients were utilized in the initial growth phase. The only apparent difference between Plots X-1 and IX-1 was the time of year of transplanting.

PLOTS XI AND XII (TABLE 10)

On September 17, 1973, 286 days after transplanting Plot XI-1 with *Syringodium*, a final account was made, but as reported on February 3, 1973, it was impossible to make a distinction be-

TABLE 10. GROWTH SURVEYS OF PLOTS XI-1 AND XII-1.
Plot XI-1. *Syringodium* clumps transplanted 11-14-72, 1 row of 10 clumps.
Plot XII-1. Transplanted 12-6-72, 1 row of 5 *Thalassia* clumps alternating with 5 *Syringodium* clumps.

		1972		1973			Removal
DATE		12-6	12-20	2-8	5-22	6-29	9-17
PERCENTAGE SURVIVAL	XI-1	100G	100**	100**	100**	100G	100G
	XII-1 *Thalassia*	100G	100**	100**	60**	100G▲	100G
	Syringo-dium	100G	100**	100**	80**	100▲	100G
CONDITIONS					turbid water		
SURVEY					relocation difficult		
INVASION OF OTHER SEAGRASSES				*Syringo-dium* beds over-growing XI-1	*Syringo-dium* beds over-growing XI-1	*Syringo-dium* beds over-growing XI-1	*Syringo-dium* beds over-growing XI-I
PRESENCE OF DRIFT ALGAE					*Hypnea*		

G - green leaves
** - fair condition
▲ - reappearance of leaves

tween original clumps and those of the overgrowing natural *Syringodium* bed.

On January 16, 1974, 407 days after transplanting, an extra checkup showed a thinning out of the border of the natural bed and four spreading clumps in a line could be distinguished. This thinning out was probably due to winter temperatures.

On September 17, 1973, 211 days after transplanting in Plot XII, a final check accounted for all the transplanted *Syringodium* and *Thalassia* clumps.

In these experiments, *Syringodium* was transplanted for the first time and both plots maintained a 100% survival. Figure 34 showed the spreading of the rhizome and root system and the new shoot formation in Plot XII-1 after 211 days. The spreading of *Syringodium* rhizomes in Plot XI-1 was so effective that single clumps had integrated into an adjacent *Syringodium* bed.

Thalassia in Plot XII-1 did fairly well, and a removed representative clump showed three rhizomes of 16.5 cm, 14.0 cm and 10.2 cm length (Figure 34), not-withstanding an unfavorable aerobic substrate similar to that in Plots IX-1 and X-1. Again, transfer of substrate could possibly have accounted for the growth. Water temperature at transplanting was 23.5°C in December, decreasing to 17.0°C in February and gradually increasing thereafter. Transplanting was thus done in a semi-dormant stage and results were as in Plot X-1, 100% survival. In May 1973, with a temperature of 27.0°C there seemed to be a mortality of 40% but one month later 100% of the clumps showed new blade growth.

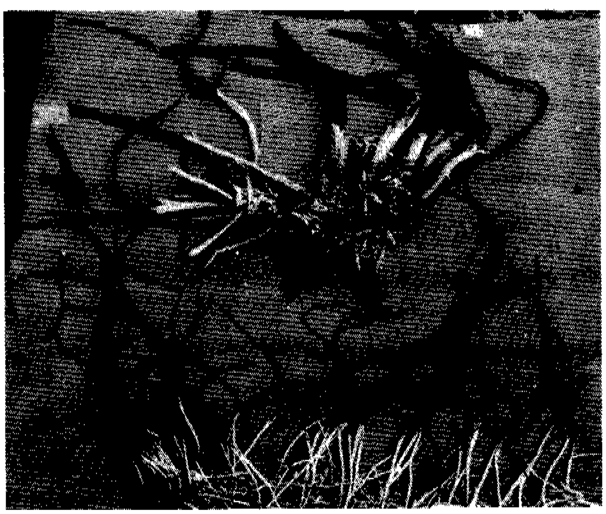

Figure 34. Plot XII-1: rhizome growth of a *Thalassia* clump and *Syringodium* clump, both unanchored.

CONCLUSIONS

Transplanting of terrestrial plants is a common practice. One of the prerequisites for a young tree to grow is a favorable environment surrounding its root system. Therefore, when transplanting, precautions were taken in order not to disturb this important factor. One of these precautions is to "ball" the root system. Another is to prepare the receiving soil by adding soil of the proper composition, adjusting the pH, and furnishing necessary nutrients and moisture.

In transplanting submerged plants, these precautions had not been taken or were overlooked, because presumably the biggest problem to overcome was the erosive wave action. All previous efforts have focused mainly upon the use of protective devices or anchoring devices (Phillips, 1960; Kelly et al., 1971; Eleuterius, 1972b). The principle of the "ball" technique had not been practiced and the principle of preparing the receiving soil seemed impractical and impossible due to fluctuations in salinity, pH, and nutrients in the interfacial waters (substrate/water column). Gradually more and more studies of estuarine substrates were undertaken (Ginsburg and Lowenstam, 1958; Gordon, 1960; Brafield, 1964; Fenchel and Jansson, 1966; Wood et al., 1969). Eleuterius (1972a, b) found that seagrasses *(Thalassia)* could withstand exposure to low salinities for long periods, but suggested that analyses for salinity stratification and pH differentiation of interstitial water of the substratum would be important to evaluate growth possibilities. He studied the redox potential of the substratum but, disappointingly, found great differences within the same area of a few square feet. Patriquin (1972) observed a nitrogen deficiency in the environment and found nitrogen fixation by anaerobic bacteria in the rhizosphere of *Thalassia*. He also mentioned that the most favorable substrate for *Thalassia* was anaerobic, aerobic for *Halodule*, while *Syringodium* could do well in either. Wicks (*unpublished*, McKendree College, Lebanon, Illinois) isolated anaerobic nitrogen-fixing bacteria at the root and rhizome system of *Thalassia* from Big Cockroach Bay (Tampa Bay) and from surface and core samples of substrate of Big Bend (Ruskin, Tampa Bay). Chemical analyses of these samples (Table 11) show nitrogen values much lower than found by van Breedveld (1966) in seagrass leaves (Table 12). These findings should direct us to pay more attention to the type of receiving substrate when transplanting seagrasses, especially *Thalassia* and *Halodule*, and endeavor to make the substrate more suitable for these grasses or to select specific favorable substrate. The result of our experiments point to these necessities.

Although these were preliminary experiments lacking a large number of transplants, the variety of locations and methods and the duration of these growth studies were adequate to make conclusions and form some guidelines for further experiments.

1. Transplanting of clumps with four to seven short

TABLE 11. ANALYSIS OF SURFACE-CORE SEDIMENTS FROM TAMPA BAY, FLORIDA

	Surface-core sediments Cockroach Bay site	Surface-core sediments Ruskin site
Temperature	31C°	34.5C°
Salinity	32.85‰	28‰
Pr g/100 ml	1.8	1.3
PO_4 -P ppm	2.176	3.095
NO_3 -N ppm	.1181	.1245
NH_3 -N ppm	71.0	71
SiO_2 -Si ppm	4.85	5.75
NO_2 -N ppm	.0034	.0033

TABLE 12. COMPARATIVE ANALYSIS OF SEAGRASSES AND ALGAE

	SEAGRASS			ALGAE			
Elements	May 1964	June 1964	July 1964	Norwegian (g)	Pachymenia (h)	Durvillea (h)	Rockweed (i)
N%	2.704	1.610	1.890	1.467	1.55-2.00	0.89-1.06	1.76
P%	0.864	0.857	0.676	0.211	0.10	0.12	0.18
K%	0.846	0.857	—	1.28	0.95-1.11	1.55-2.08	2.83
Fe%	0.120	0.053	0.106	0.0896	—	—	0.01
Cu%	0.00317	0.00320	0.00252	0.000635	—	—	0.02
Mn ppm of dry weight	11.70	802.3	—	1235	—	—	160
Moisture %	47.83	64.39	68.29	—	—	—	13.5
Mannitol %	—	0.4185	0.4381	3.0	—	—	5.3-17.3
Alginic acid %	0	0	0	—	—	—	17.4-25.3

Figures are % of dry weight, unless indicated.
Analyses in duplicate or triplicate.
Seagrasses in May contained 60% *Thalassia testudinum*.
Seagrasses in June and July were 99% *Syringodinium filiforme*.

g = Senn et al., 1961
h = Francki, 1960
i = Booth, 1953

shoots, including the sediment, is preferable to any other known methods, including those using anchoring devices.

2. Planting of these clumps in several rows with the transferred sediment contiguous between the clumps in each row and between the rows is advisable in substrate not favorable to the specific seagrass. In favorable substrates, the space between clumps can be as great as 30 cm.
3. Transplanting preferably should be done when the seagrass is in a semidormant state; e.g., winter months, with a temperature of ≤21.0° C, thereby giving the plants the opportunity to become stabilized. Healthy clumps should be selected.
4. Use of hormones has not been an advantage, especially when using single sprigs with apices. It is expensive, time-consuming, and partly washes away the sediment around the rhizome/root system, and also exposes the system.
5. Checkups, respectively sixty-seven months and thirty-six months after mechanical denudation (Godcharles, 1971), and natural denudation (Camp et al., 1971) indicated that siltation can transform a denuded area from an anaerobic to an aerobic condition, regrowth of *Thalassia* is very slow or negative and *Halodule* will take over (Phillips, 1960). Although the natural beds from which the clumps were obtained in these experiments recovered in a short time, additional investigations are needed to determine how many plants can be removed from natural beds without damage. It is also suggested that experiments be conducted to determine feasibility of establishing seedling nurseries. Additionally, direct planting of seagrass seeds should be further researched.

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